Remarks/Arguments

Prior to this response, claims 1-24 were pending; claims 1-24 were rejected in the above-referenced Office action.

In this response, claims 2 and 14 are canceled; claims 1, 3-13, and 15-24 are pending.

Rejection of claims 1-7, 10-19, and 22-23 as being anticipated by Stenzel (US 5,109,389)

Stenzel discloses a cold crucible for melting and directional solidification of metals placed in the crucible. For embodiments with multiple coils (sub-coils), Stenzel teaches varying the physical parameters of each sub-coil to achieve directional melting/cooling from the bottom of the crucible. See, for example, Stenzel FIG. 4, and the specification: "A second sub-coil 37, having windings 38-41, is located in the lower region of the crucible 4. The second sub-coil 37 is shorter and has a lower number of turns than the first sub-coil 36." col. 10, lines 9-12. The Examiner cites a "switching means 50, 45, 46, 47" in Stenzel. The cited switching means is illustrated in FIG. 5 and described in the specification: "A capacitor 45 is connected in parallel to the coil 2, so that the coil 2 forms a resonant circuit with the capacitor 45. An inductance 46, that causes a frequency modification and that can be shorted by a switch 50, is connected in the series with this parallel resonant circuit 2, 45. A DC power source 47 is also connected parallel to the AC power supply. 34 and to the parallel resonant circuit 2, 45." col. 11, lines 48-53. Therefore switch 50 does <u>not</u> switch coils (sub-coils) as suggested by the Examiner; switch 50 is used to change the resonant frequency of the coil (load) circuit. Stenzel discloses a cold crucible, which consists of isolated vertical segments as shown, for example, in Stenzel FIG. 2a and FIG. 2b where elements 5, 6 and 7 represent typical vertical segments. Cooling tubes 8 and 9 in representative segment 6 circulate a cooling medium in the vertical direction via intake 10 and discharge 11.

Claim 1 recites an apparatus for directional solidification of a metal comprising a vessel for containing a molten mass of the metal; a plurality of induction coils surrounding the height of the exterior of the vessel; a switching means for each of the plurality of induction coils, each of the switching means having a first switch terminal and a second switch terminal, each of the first switch terminals exclusively connected to a first coil terminal of each of the plurality of induction coils; a single source of ac current having a first source terminal and a second source terminal, the first source terminal connected to all of the second

switch terminals, the second source terminal connected to all of the second coil terminals; and a control means for selectively opening and closing each of the switching means to progressively decrease the induced heat from the bottom to the top of the molten mass of the metal in the vessel. Stenzel does not disclose a switching means for each of the plurality of induction coils, each of the switching means having a first switch terminal and a second switch terminal, each of the first switch terminals exclusively connected to a first coil terminal of each of the plurality of induction coils; a single source of ac current having a first source terminal and a second source terminal, the first source terminal connected to all of the second switch terminals, the second source terminal connected to all of the second coil terminals; and a control means for selectively opening and closing each of the switching means to progressively decrease the induced heat from the bottom to the top of the molten mass of the metal in the vessel, as recited, in part, in claim 1. Applicants submit claim 1 is not anticipated by Stenzel, since Stenzel does not disclose each of the claimed elements, arranged as in the claim.

Claim 3 recites the apparatus of claim 1 further comprising a means for selectively cooling the molten mass of the metal in the vessel progressively from the bottom to the top of the molten mass of the metal in the vessel, the means for selectively cooling disposed exteriorly around the height of the vessel. As noted above, the Stenzel cooling means is integrated with the crucible to cool the crucible. Stenzel's required vertical arrangement of crucible segments in which the cooling tubes are located is not a means for selectively cooling the molten mass of the metal in the vessel progressively from the bottom to the top of the molten mass of the metal in the vessel, the means for selectively cooling disposed exteriorly around the height of the vessel, as recited in claim 3. Applicants submit that claim 3 is not anticipated by Stenzel.

Claim 4 recites the apparatus of claim 3 wherein the means for selectively cooling comprises a cooling medium flowing in each of the plurality of induction coils. Stenzel does not disclose a cooling medium flowing in each of the plurality of induction coils for selectively cooling the molten mass of the metal in the vessel progressively from the bottom to the top of the molten mass of the metal in the vessel. Applicants submit that claim 4 is not anticipated by Stenzel.

Claim 5 recites the apparatus of claim 1 further comprising a means for cooling the molten mass of the metal in the vessel from the bottom of the molten mass. Stenzel, as discussed above, does not disclose the apparatus of claim 1, further comprising a means for cooling the molten mass of the metal in the vessel from the bottom of the molten metal. Applicants submit that claim 5 is not anticipated by Stenzel.

Claim 6 recites the apparatus of claim 3 further comprising a means for cooling the molten mass of the metal in the vessel from the bottom of the molten mass. Stenzel, as discussed above, does not disclose the apparatus of claim 3, further comprising a means for cooling the molten mass of the metal in the vessel from the bottom of the molten metal. Applicants submit that claim 6 is not anticipated by Stenzel.

Claim 7 recites the apparatus of claim 1 further comprising a means for pushing the solidified metal out of the vessel. Stenzel does not disclose a means for pushing the solidified metal out of the vessel in combination with the elements of claim 1. Applicants submit that claim 7 is not anticipated by Stenzel.

Claim 10 recites a method of directional solidification of a molten mass of a metal comprising the steps of placing the molten mass of the metal in a vessel surrounded with a plurality of inductions coils connected to a single ac power source; selectively switching an ac current to each of the plurality of induction coils from the single ac power source to heat the molten mass of the metal in the vessel; and progressively decreasing the applied heat by induction from the bottom to the top of the molten mass of the metal in the vessel to solidify the molten mass in the vessel from the bottom to the top of the vessel. Stenzel, as discussed above, does not disclose all the steps in claim 10; Applicants submit that claim 10 is not anticipated by Stenzel.

Claim 11 recites the method of claim 10 further comprising the step of progressively cooling the molten mass of the metal in the vessel from the bottom to the top of the molten mass of the metal in the vessel. Stenzel, as discussed above, does not disclose progressively cooling the molten mass of the metal in the vessel from the bottom to the top of the molten mass of the metal in the vessel, in combination with the steps of claim 10. Applicants submit that claim 11 is not anticipated by Stenzel.

Claim 12 recites the method of claim 10 further comprising the step of pushing the

solidified metal out of the vessel. Stenzel, as discussed above, does not disclose pushing the solidified metal out of the vessel, in combination with the steps of claim 10. Applicants submit that claim 12 is not anticipated by Stenzel.

Claim 13 recites an apparatus for directional solidification of a metal comprising a susceptor vessel for containing a molten mass of the metal; a plurality of induction coils surrounding the height of the exterior of the susceptor vessel; a switching means for each of the plurality of induction coils, each of the switching means having a first switch terminal and a second switch terminal, each of the first switch terminals exclusively connected to a first coil terminal of each of the plurality of induction coils; a single source of ac current having a first source terminal and a second source terminal, the first source terminal connected to all of the second switch terminals, the second source terminal connected to all of the second coil terminals; and a control means for selectively opening and closing each of the switching means to progressively decrease the induced heat from the bottom to the top of the molten mass of the metal in the vessel. Stenzel does not disclose an apparatus for directional solidification of a metal comprising a susceptor vessel for containing a molten mass of the metal, a switching means for each of a plurality of induction coils, each of the switching means having a first switch terminal and a second switch terminal, each of the first switch terminals exclusively connected to a first coil terminal of each of the plurality of induction coils, a single source of ac current having a first source terminal and a second source terminal, the first source terminal connected to all of the second switch terminals, the second source terminal connected to all of the second coil terminals, and a control means for selectively opening and closing each of the switching means to progressively decrease the induced heat from the bottom to the top of the molten mass of the metal in the vessel, as recited, in part, in claim 13. Applicants submit that claim 13 is not anticipated by Stenzel, since Stenzel does not disclose each of the claimed elements, arranged as in the claim.

Claim 15 recites the apparatus of claim 13 further comprising a means for selectively cooling the molten mass of the metal in the vessel progressively from the bottom to the top of the molten mass of the metal in the vessel, the means for selectively cooling disposed exteriorly around the height of the vessel. As noted above, the Stenzel cooling means is integrated with the crucible and cools the crucible to prevent heating of the crucible.

Stenzel's required vertical arrangement of crucible segments in which the cooling tubes are located is not a means for selectively cooling the molten mass of the metal in the vessel progressively from the bottom to the top of the molten mass of the metal in the vessel, the means for selectively cooling disposed exteriorly around the height of the vessel, as recited in claim 15. Applicants submit that claim 15 is not anticipated by Stenzel.

Claim 16 recites the apparatus of claim 15 wherein the means for selectively cooling comprises a cooling medium flowing in each of the plurality of induction coils. Stenzel does not disclose a cooling medium flowing in each of the plurality of induction coils for selectively cooling the molten mass of the metal in the vessel progressively from the bottom to the top of the molten mass of the metal in the vessel. Applicants submit that claim 16 is not anticipated by Stenzel.

Claim 17 recites the apparatus of claim 13 further comprising a means for cooling the molten mass of the metal in the vessel from the bottom of the molten mass. Stenzel, as discussed above, does not disclose the apparatus of claim 13 further comprising a means for cooling the molten mass of the metal in the vessel from the bottom of the molten mass. Applicants submit that claim 17 is not anticipated by Stenzel.

Claim 18 recites the apparatus of claim 15 further comprising a means for cooling the molten mass of the metal in the vessel from the bottom of the molten mass. Stenzel, as discussed above, does not disclose the apparatus of claim 15 further comprising a means for cooling the molten mass of the metal in the vessel from the bottom of the molten mass. Applicants submit that claim 18 is not anticipated by Stenzel.

Claim 19 recites the apparatus of claim 13 further comprising a means for pushing the solidified metal out of the vessel. Stenzel does not disclose a means for pushing the solidified metal out of the vessel in combination with the elements of claim 13. Applicants submit that claim 19 is not anticipated by Stenzel.

Claim 22 recites, in part, a method of directional solidification of a molten mass of a metal comprising the steps of placing the molten mass of the metal in a susceptor vessel surrounded with a plurality of inductions coils connected to a single ac power source, selectively switching an ac current to each of a plurality of induction coils from the single ac power source to heat the susceptor vessel to heat by conduction and radiation the molten

mass of the metal in the susceptor vessel, and progressively decreasing the applied heat by induction from the bottom to the top of the susceptor vessel to solidify the molten mass in the susceptor vessel from the bottom to the top of the vessel. Stenzel, as discussed above, does not disclose the steps in claim 22; Applicants submit that claim 22 is not anticipated by Stenzel.

Claim 23 recites the method of claim 22 further comprising the step of progressively cooling the molten mass of the metal in the susceptor vessel from the bottom to the top of the molten mass of the metal in the vessel. Stenzel, as discussed above, does not disclose progressively cooling the molten mass of the metal in the vessel from the bottom to the top of the molten mass of the metal in the vessel, in combination with the steps of claim 22. Applicants submit that claim 23 is not anticipated by Stenzel.

<u>Rejection of claims 1, 3-7, 9-13, 15-19 and 21-24 as being anticipated by Tsuda et al (US 6,307,875)</u>

The Tsuda et al apparatus is a generally funneled-shaped cold induction crucible used to <u>melt</u> (not solidify) a metal (col. 6, lines 5-14). Two induction coils are used. The first coil 5 is used <u>exclusively</u> to melt the metal placed in the cold crucible. The second coil 6 is used <u>exclusively</u> to melt the solid layer of skull 14 around the bottom tapping portion (2) of the cold crucible when the molten metal in the crucible is ready to be tapped from the bottom of the cold crucible (col. 7, lines 62-64), and to control the flow rate of the molten metal through the tap by adjusting the frequency of the current supply to coil 6, which controls the amount of skull in the tap used to restrict flow through the tap. As described in Tsuda et al, a cold crucible process includes formation of a solid layer of skull 14 between the crucible wall (but not a solid metal mass in the crucible) and the molten metal in the crucible to prevent reaction of the molten metal with the material of the crucible wall. In the cold crucible induction process, the crucible wall 4 has interior cooling channels 4a to form the layer of skull by freezing metal in contact with the wall. Coil 5 is powered exclusively from melt-use power source 7 and coil 6 is powered exclusively from tapping-use power source 8. Control means 12 controls the melting in the crucible and pouring from the crucible. The Examiner refers to Figure 8 of Tsuda et al. In this figure, a starting block 19 is inserted into the tapping portion 2 of the crucible to pull the solidified skull 14 in the tap out by force applied by

drawing device 20 when molten metal is to be tapped from the crucible. In the present invention, the entire solidified metal mass can be pushed out of the vessel (paragraph 0018 of the filed specification). In FIG. 12(A)-12(C) Tsuda et al also discloses a third embodiment (col. 12, line 43 through col. 14, line 35) of a furnace that includes a cylindrical wall (33) chamber. However that chamber is combined with a funnel-shaped tapping portion (21) in the bottom wall (34) of the chamber that functions similarly to the Tsuda et al funnel-shaped furnaces. Therefore Tsuda et al does not teach a switching means for each of the plurality of induction coils, each of the switching means having a first switch terminal and a second switch terminal, each of the first switch terminals exclusively connected to a first coil terminal of each of the plurality of induction coils; a single source of ac current having a first source terminal and a second source terminal, the first source terminal connected to all of the second switch terminals, the second source terminal connected to all of the second coil terminals; and a control means for selectively opening and closing each of the switching means to progressively decrease the induced heat from the bottom to the top of the molten mass of the metal in the vessel, as recited, in part, in claim 1. Anticipation requires that Tsuda et al teaches each of the claimed elements, as arranged in the claim. Regarding claim 1, Tsuda et al does not teach a means for selectively applying ac current to each of the plurality of induction coils to inductively heat the molten mass of the metal in the vessel with applied heat progressively decreasing from the bottom to the top of the molten mass of the metal in the vessel, whereby the molten mass solidifies in the vessel from the bottom to the top of the vessel. Tsuda et al teaches using a plurality of induction coils wherein some of the induction coils are dedicated to melting a metal in a cold crucible and the remaining induction coils are dedicated to controlling the melting of the skull formed in a bottom tap of the crucible to control the flow rate of molten metal from the crucible. For the above reasons, Applicants submit that claim 1 is not anticipated by Tsuda et al. For the same reasons, Applicants submit that claims 3-7, and 9, which are directly or indirectly dependent upon claim 1, are not anticipated by Tsuda et al.

Claim 10, recites, in part, the steps of selectively switching an ac current to each of the plurality of induction coils from a single ac power source to heat the molten mass of the metal in the vessel; and progressively decreasing the applied heat by induction from the

bottom to the top of the molten mass of the metal in the vessel to solidify the molten mass in the vessel from the bottom to the top of the vessel. For the above reasons, Applicants submit that claim 10 is not anticipated by Tsuda et al. For the same reasons, Applicants submit that claims 11 and 12, which are directly dependent upon claim 10, are not anticipated by Tsuda et al.

Claim 13 recites, in part, a switching means for each of the plurality of induction coils, each of the switching means having a first switch terminal and a second switch terminal, each of the first switch terminals exclusively connected to a first coil terminal of each of the plurality of induction coils; a single source of ac current having a first source terminal and a second source terminal, the first source terminal connected to all of the second switch terminals, the second source terminal connected to all of the second coil terminals; and a control means for selectively opening and closing each of the switching means to progressively decrease the induced heat from the bottom to the top of the molten mass of the metal in the vessel. For the above reasons, Applicants submit that claim 13 is not anticipated by Tsuda et al. For the same reasons, Applicants submit that claims 15-19, and 21, which are directly or indirectly dependent upon claim 13, are not anticipated by Tsuda et al.

Claim 22 recites, in part, the steps of selectively switching an ac current to each of a plurality of induction coils from a single ac power source to heat the susceptor vessel to heat by conduction and radiation the molten mass of the metal in the susceptor vessel, and progressively decreasing the applied heat by induction from the bottom to the top of the susceptor vessel to solidify the molten mass in the susceptor vessel from the bottom to the top of the vessel. For the above reasons, Applicants submit that claim 22 is not anticipated by Tsuda et al. For the same reasons, Applicants submit that claims 23 and 24, which are directly dependent upon claim 22, are not anticipated by Tsuda et al.

<u>Rejection of claims 8 and 20 as being obvious over Stenzel in view of Fukuzawa et al (US 5,416,796)</u>

Stenzel is discussed above. Fukuzawa et al discloses an induction cold crucible that has a stationary upper part 11 and a lower closed-bottom part 12 that can be lowered away from the upper part as a columnar metal 19 is formed within the crucible. Solid cold metal 20 is added to molten metal in the crucible as the bottom part of the crucible is lowered. Molten metal surface thermometer 23 senses the temperature of molten metal in the crucible, and

when the sensed temperature exceeds a desired range, additional cold material is added to the melt (col. 3, lines 55-61). Molten metal surface level gauge 24 measures the level of molten metal in the crucible, and when the sensed level exceeds a desired range, lowering of the bottom part of the crucible is stopped (col. 3, lines 62-68).

Claim 8 recites the apparatus of claim 1 further comprising a sensor means to sense the progress of solidification of the mass of molten metal from the bottom to the top of the vessel. Claim 1, recites, in part, a switching means for each of the plurality of induction coils, each of the switching means having a first switch terminal and a second switch terminal, each of the first switch terminals exclusively connected to a first coil terminal of each of the plurality of induction coils; a single source of ac current having a first source terminal and a second source terminal, the first source terminal connected to all of the second switch terminals, the second source terminal connected to all of the second coil terminals; and a control means for selectively opening and closing each of the switching means to progressively decrease the induced heat from the bottom to the top of the molten mass of the metal in the vessel. Applicants submit that Stenzel in combination with Fukuzawa et al does not make obvious use of a sensor, as recited in claim 8, to sense the progress of solidification of a molten mass in a vessel as inductively heated in claim 1.

Claim 13, recites an apparatus for directional solidification of a metal comprising a susceptor vessel for containing a molten mass of the metal; a plurality of induction coils surrounding the height of the exterior of the susceptor vessel; a switching means for each of the plurality of induction coils, each of the switching means having a first switch terminal and a second switch terminal, each of the first switch terminals exclusively connected to a first coil terminal of each of the plurality of induction coils; a single source of ac current having a first source terminal and a second source terminal, the first source terminal connected to all of the second switch terminals, the second source terminal connected to all of the second coil terminals; and a control means for selectively opening and closing each of the switching means to progressively decrease the induced heat from the bottom to the top of the molten mass of the metal in the vessel. Claim 20, which is dependent upon claim 13, recites a sensor means to sense the progress of solidification of the mass of molten metal from the bottom to the top of the vessel. Applicants submit that Stenzel in combination with

Fukuzawa et al do not make obvious use of a sensor, as recited in claim 20, to sense the progress of solidification of a molten mass in a susceptor vessel as inductively heated in claim 13.

Rejection of claims 9 and 21 as being obvious over Stenzel in view of Tsuda et al

Stenzel and Tsuda et al are discusses above.

Claim 9 recites the apparatus of claim 1 further comprising a feedback means for adjusting the means for selectively applying ac current to each of the plurality of induction coils to control the progress of solidification of the mass of molten metal from the bottom to the top of the vessel. Nether Stenzel or Tsuda et al disclose an apparatus for directional solidification of a metal comprising a vessel for containing a molten mass of the metal; a plurality of induction coils surrounding the height of the exterior of the vessel; a switching means for each of the plurality of induction coils, each of the switching means having a first switch terminal and a second switch terminal, each of the first switch terminals exclusively connected to a first coil terminal of each of the plurality of induction coils; a single source of ac current having a first source terminal and a second source terminal, the first source terminal connected to all of the second switch terminals, the second source terminal connected to all of the second coil terminals; and a control means for selectively opening and closing each of the switching means to progressively decrease the induced heat from the bottom to the top of the molten mass of the metal in the vessel, as recited in claim 1. Applicants submit that claim 9, which is dependent on claim 1, is not obvious over Stenzel view of Tsuda et al.

Claim 21 recites the apparatus of claim 13 further comprising a feedback means for adjusting the means for selectively applying ac current to each of the plurality of induction coils to control the progress of solidification of the mass of molten metal from the bottom to the top of the vessel. Claim 13 recites an apparatus for directional solidification of a metal comprising a susceptor vessel for containing a molten mass of the metal; a plurality of induction coils surrounding the height of the exterior of the susceptor vessel; a switching means for each of the plurality of induction coils, each of the switching means having a first switch terminal and a second switch terminal, each of the first switch terminals exclusively connected to a first coil terminal of each of the plurality of induction coils; a single source of ac current having a first source terminal and a second source terminal, the first source

terminal connected to all of the second switch terminals, the second source terminal connected to all of the second coil terminals; and a control means for selectively opening and closing each of the switching means to progressively decrease the induced heat from the bottom to the top of the molten mass of the metal in the vessel. Applicants submit that claim 21, which is dependent on claim 13, is not obvious over Stenzel view of Tsuda et al.

Applicants respectfully request allowance of all pending claims.

Respectfully submitted,

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